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Study on strength of (1%) glass fiber reinforced, (50%) fly ash and (100%) quarry dust concrete

P. Sudheer*, M. G. Muni Reddy, S. S. S. V. Gopala Raju

Department of Civil Engineering, MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India.

Correspondence Address: *Sudheer Ponnada, Department of Civil Engineering, MVGR College of Engineering, Vizianagaram, Andhra Pradesh, India.

Abstract

Concrete is the most popular construction material in the world and extensively used due to rapid infrastructural growth. This makes scarcity of ingredients and increases the cost of concrete. In this concern, there is a need to identify alternate materials for the ingredients of concrete, especially for cement and fine aggregate. Natural river sand is one of the key ingredients of concrete, which is becoming expensive due to excessive cost of transportation from sources. The production of cement has diminished the limestone reserves in the world and requires a great consumption of energy. To overcome these problems, there is a need of cost effective alternative and innovative materials. The alternative materials are preferably waste products such as quarry dust and fly ash in order to reduce the cost of concrete. The main objective of this study is to study the mechanical characteristics of concrete by various combinations of concrete and fine aggregate replaced by fly ash, quarry dust and glass fibers. It is found that the concrete made with cement replaced with 50% of fly-ash, fine aggregate replaced by 100% quarry dust and 1% glass fiber performed better than other combinations in terms of strength.

Keywords: Fly-ash, Quarry Dust, Glass Fiber, Cement, Fine Aggregate, Coarse Aggregate

Introduction

Increasing extraction of natural sand from river beds causing many problems, loosing water retaining sand strata, deepening of the river course sand using bank slides, loss of vegetation on the bank of rivers, exposing the Intake well of water supply schemes, disturbs the aquatic life as well as affecting agriculture due to lowering the underground water table etc are few examples. In past decade variable cost of naturals and used as fine Aggregate in concrete increased the cost of construction.

The world wide consumption of fine aggregate in concrete production is very high, and several developing countries have encountered difficulties in meeting the supply of natural fine aggregate in order to satisfy the increasing needs of infrastructural development in recent years. To overcome the stress and demand for river fine aggregate, researchers and practitioners in the construction industries have identified some alternative materials such as fly ash, slag, limestone powder and siliceous stone powder. In India attempts have been made to replace river sand with quarry dust. The successful utilization of quarry dust as fine aggregate would turn this waste material that causes disposal problem into a valuable resource.

The use of Fly Ash in concrete is desirable because of benefits such as useful disposal of a by-product, increased workability, reduction of cement consumption, increased sulphate resistance, increased resistance to alkali-silica reaction and decreased permeability. However, the use of fly ash leads to a reduction in early strength of concrete. The decrease in workability by the addition of quarry dust is reduced by the addition of fly ash. The concurrent use of the two by-products will lead to a range of economic and environmental benefits.

They are Low Thermal (LT) fly ash operating at combustion temperature of 750-850 degrees centigrade and High Thermal (HT) fly ash operating at the temperature of 900-1400 degrees centigrade. It is observed that both LT and HT fly ashes behave distinctly different. Use of fly ash in structural concrete is acceptable as per IS 456.

There are about 70 thermal power plants in the country, which are currently producing about 100 million tons of fly ash per annum. Out of this huge quantity of fly ash, hardly less than 5% is being put for gainful purposes like brick making, cement manufacture, void filling in tunnels, backfill, sludge stabilization, glass manufacture, agriculture, soil stabilization etc, leaving a massive portion of the ash for storage in ash ponds. In spite of some inherent problems associated with fly ash utilization, the encouraging engineering properties of the material prompted engineering community to utilize it in bulk quantities for construction purpose, which not only helps to dispose it off but also to preserve the top fertile soil from using it for several purposes.

Fly ash

The word "fly ash" is commonly used as generic terminology for the waste product due to burning of coal in the boiler of a thermal power plant. It is defined as ash generated by burning of ground or pulverized or crushed coal or lignite in boilers. Fly ash is a fine grained pozzolonic material, generally spherical in shape. The standard categories of fly ash are two classes- class C and class F. While the fly ash containing equal to or more than 10% lime is classified as class C, the one containing less than 10% lime is classified as class F. There are two more distinct behavior of fly ash based on boiler operating parameters.

Fibres

Concrete made with Portland cement has certain characteristics. It is relatively strong in compression but weak in tension to brittle. The load tension weakness can overcome by the use of fibres. The use of fibre matrix in concrete also alters the behaviour of the fibre matrix after it is cracked, thereby improving its toughness. The advantages of fibre reinforced concrete over plain concrete that have been recognized so far are listed below.

- Increase higher strength in tension
- Increase ductility
- Improves the toughness
- Increase resistance to impact and dynamic loads
- Minimum crack propagation under working loads
- Increase flexibility tension
- Increase ultimate strength

Glass Fibres

Glass fibres are recent introduction in making fibre reinforced concrete. Glass fibres are available in different forms such as continuous roving, woven roving mats, chopped strand mats and chopped strands for various applications.

Different types of glass fibres are

- E-glass (electrical) - lower alkali content, good tensile, compressive strength and stiffness, good electrical properties and relatively low cost.
- C-glass (chemical)-best resistance to chemical attack.
- R, S or T-glass-manufacture's trade names for equivalent fibres having higher tensile strength and modulus of elasticity than E glass.

(E-glass is the most commonly used fibre in reinforced concrete)

Glass Fibre Reinforced Concrete:

Glass fibre reinforced concrete (GFRC) is a proven engineered composite building material consisting of Portland cement, aggregate, water, glass fibre reinforcement and additives. The glass fibre reinforcement results in a product with much higher flexural strength than normal concrete, allowing its use in thin-wall casting applications. Fibres are added to a concrete mix which normally contains cement, water and fine and coarse aggregate. Fibres are generally randomly distributed in the concrete; however, processing the concrete so that the fibres become aligned in the direction of applied stress will result in even greater tensile or flexural strength.

The chief advantages of Glass fibre reinforced concrete (GFRC) are:

1. Highly moisture resistant
2. The lightweight allows for reduced erection and transport costs due to ease and speed of handling.
3. High Compressive strength
4. Ability to reproduce fine surface details.
5. Low maintenance requirements.
6. Low coefficients of thermal expansion.
7. High Fire Resistance.
8. Environmentally Friendly

Objectives of present study:

Various researches have used alternative materials as a replacement for conventional materials in concrete. After investigating the works done by various researches, the objectives of the present work is drawn.

1. Determining the physical properties of Quarry dust and comparing with natural sand.
2. Effective utilization waste materials like (quarry dust and fly ash) in concrete.
3. Determining the variation of strength properties by replacing Fine aggregate with Quarry dust fully and cement with Fly ash partially along with 1% glass fibre.
4. Cost reduction of concrete.

Experimental Study

Physical properties of Quarry Dust:

Various physical properties of Quarry dust and natural sand are determined in the laboratory and reported in Table 1.

Various combinations of mixes are tried and the same is shown in Table 2. The workability values of all four mixes are shown in Table 3. The compressive strength values for 7 days, 28 days and 56 days curing period for all four mixes are shown in Tables 4 to 7. The relative comparison of compressive strengths of all four mixes is shown in Fig.1.

Table 1. Physical properties of Quarry Dust and Natural sand.

S. NO.	PROPERTY	Quarry dust	Natural sand
1.	Specific gravity	2.38	2.25
2.	Sieve analysis	Zone II (coarser)	Zone II
3.	Bulking	70% @ 8% water content	
4.	Bulk density	1670 kg/m^3	1.66gm/cc

Table 2: Various Mixes with different combination of materials.

S.No	MIX	CEMENT	FLYASH	SAND	QUARRY DUST(FA)	CA	FIBER
1	MIX 1	100%	0	100%	0	100%	-
2	MIX2	100%	0	0	100%	100%	-
3	MIX3	50%	50%	0	100%	100%	-
4	MIX4	50%	50%	0	100%	100%	1%

Table 3: Workability of various Mixes.

Mix Designation	Slump Value (mm)	Vee-bee (seconds)
MIX 1	70	2
MIX 2	65	2.5
MIX 3	60	3
MIX 4	55	4

Table 4: Mix 1 Compressive strength (Mpa).

S. no	No. of days	S1	S2	S3	Avrg. Strength (MPa)
1	7 days	38	38.4	39.2	38.53
2	28 days	50	51.2	51	50.73
3	56 days	55.2	53.6	56.8	55.2

Table 5: Mix 2 Compressive strength (Mpa).

S. no	No. of days	S1	S2	S3	Average Strength (mPa)
1	7 days	41.9	42.2	42	42.03
2	28 days	57.4	57	57.3	57.23
3	56 days	62	60	62.9	61.63

Table 6: Mix 3 Compressive strength (Mpa).

S. no	No. of days	S1	S2	S3	Average Strength (mPa)
1	7 days	15.9	17.7	17.2	16.9
2	28 days	33.1	32.5	28.7	31.43
3	56 days	42.5	40	41	41.16

Table 7: Mix 4 Compressive strength (Mpa).

S. no	No. of days	S1	S2	S3	Average Strength (mPa)
1	7 days	17.7	19.1	18.7	18.5
2	28 days	34.5	32.8	33.5	33.6
3	56 days	45	43.4	46.9	45.1

The split tensile strength of all four mixes is shown in Table. 8 and the flexure strengths are given in Table 9.

Table 8: Split tensile strengths of all four mixes.

Mix	No. of days	S1	S2	S3	Average Strength (mPa)
1	7days	3.49	2.79	3.13	3.14
2	7days	7.59	6.42	6.3	6.77
3	7days	1.97	1.71	1.89	1.86
4	7days	2.12	1.67	1.96	1.92

Table 9: Flexural strengths of all four mixes.

Mix	No. of days	S1	S2	S3	Average Strength (mPa)
1	7days	3.21	3.09	2.94	3.08
2	7days	3.82	3.78	3.61	3.74
3	7days	2.31	2.43	2.79	2.51
4	7days	3.94	4.03	3.57	3.85

The stress strain diagrams for all four mixes are shown in Fig. 2 to Fig. 5. The Young's Modulus values calculated from the stress strain curves is tabulated in Table 10.

Table 10: Young's Modulus Values for all four mixes.

S.NO.	MIX	Average Young's Modulus (MPa)
1.	MIX1	$3.43*10^4$
2.	MIX2	$4.02*10^4$
3.	MIX3	$2.79*10^4$
4.	MIX4	$3.10*10^4$

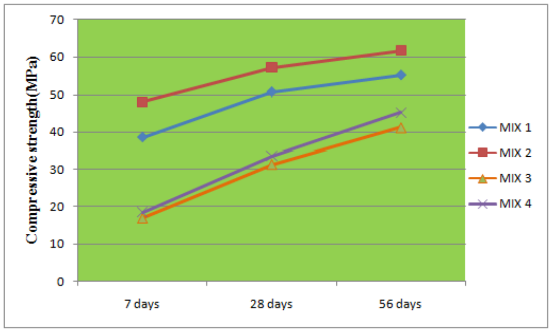

Fig. 1. Comparison of Compression strengths of all four mixes

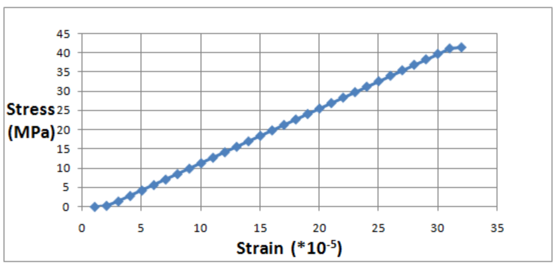

Fig. 2. Stress Strain curve for MIX1

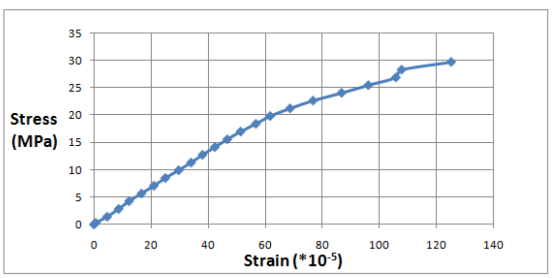

Fig. 3. Stress Strain curve for MIX2

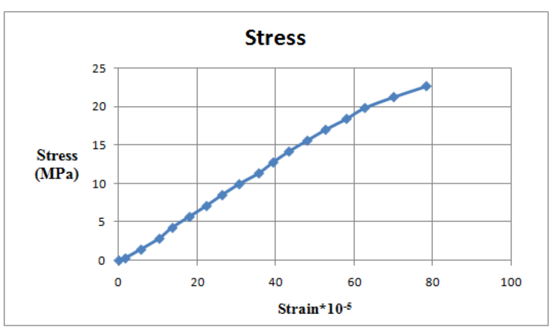

Fig. 4.Stress Strain curve for MIX 3

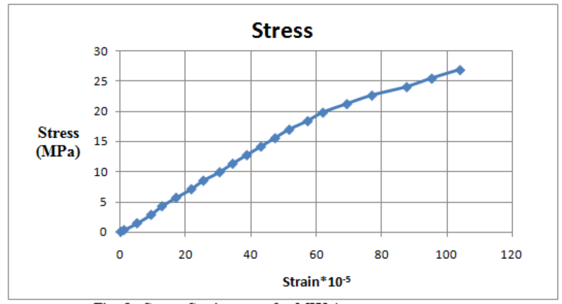

Fig. 5. Stress Strain curve for MIX 4

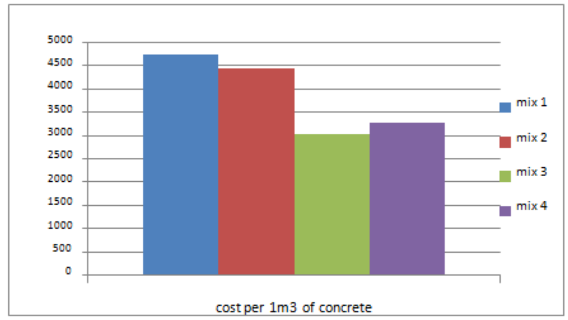

Fig. 6 Cost comparison of all four mixes.

From the cost analysis for $1m^3$ of concrete MIX 2 shows that there is a reduction in cost by 7 Percent of MIX 1 and MIX 3 shows that 36 percent cost is reduced. From this we can understand that using Quarry dust and Fly ash in concrete is very economical.

Conclusions

From the study the following conclusions are drawn.

1. Mix 2 (100% Quarry dust as FA) showed in nearly 13 percent increase in Compressive Strength at 28 days curing compared to Mix 1(conventional).
2. Mix 2 showed 50 percent increase in Split tensile strength and 23 percent increase flexure strength compared to Mix 1 conventional.
3. Mix 4 (Quarry dust 100% +Fly ash 50%+Fibre 1%) achieved 25 percent increase in flexure strength compared to Mix 1 (conventional).
4. Mix 3 (Quarry dust 100% +Fly ash 50%) gained 75 percent on compressive strength of Mix 1 at 56 days curing period.

5. Mix 4 gained 84 percent on compressive strength of Mix 1 at 56 days curing period.
6. From the cost analysis it can be concluded that using Quarry dust and Fly ash in concrete is very economical and a better solution for scarcity of materials.

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